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Report of the Workshop on Cataloguing Data Requirements from Surveys for the EAFM (WKCATDAT)

26-28 January 2011

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Executive summary

The Workshop on Cataloguing Data Requirements from Surveys for the EAFM (WKCATDAT) chaired by Dave Reid, Ireland, met in Dublin, Ireland from 26 – 28 January 2011. This meeting was delayed from the original timing of April 2010.

The main aim of the workshop was to provide a comprehensive catalogue of the data required from surveys to support all aspects of the EAFM. This catalogue was produced and is included in the report (Chapter 3). The aim was then to provide guidance on priorities for data collection on improved and enhanced EAFM surveys. This was not carried out. The membership of the workshop was largely drawn from high level fishery survey leaders and operatives. While this group included significant expertise in the EAFM, it was agreed that priorities were better set by the users of such data, rather than those whose principle task was to collect it. To complete this step in the process it was agreed that the catalogue from this meeting should be passed to appropriate ecosystem groups (e.g. WGECO, WGINOSE, WGEAWESS, WGIAB and WGOOFE). The catalogue has already been passed to WGINOSE and WGOOFE. The final aim was to report on any implications of the exercise on planning for future surveys, and this is reported in detail in Chapter 4. Finally, a report on three EAFM style surveys already in operation was included as Chapter 5.

The data needs catalogue is presented in Chapter 3. The main output is presented as a table with the data provision tasks as rows and the appropriate surveys and resource implications as columns. The rows were subdivided as follows:

- **Fish and organisms** – biological material from the trawls, including inter alia; stomachs, organs, disease and parasite registration etc, but also including acoustic data and tagging
- **Physical and chemical oceanography** – e.g. CTD, chlorophyll, oxygen, nutrients, turbidity, etc. This was subdivided by collection platform and approach:
  - Continuous underway measurements
  - Station measurements
  - Autonomic devices
  - Water movement (ADCP)
  - Nutrient sampling – Using water bottles etc
- **Biological oceanography** – principally collection of plankton and other passive biological material, using; water samplers, continuous plankton recorders, towed profiling samplers, dipped samplers and echosounders.
- **Invertebrates** - collection of invertebrate biological samples such as; infauna, epifauna, and pelagic invertebrates, each of which would require different sampling approaches.
- **Megafauna** - collection of data on mammals, seabirds, large elasmobranchs etc usually by sight survey but including towed hydrophone systems to track cetaceans underwater.
- **Habitats -** collection of data on seabed substrate, structure and relief, using acoustic seabed discrimination systems and direct camera observation. For example;
  - Towed/dropped camera systems
  - Side-scan sonar

- Multi-beam echosounder
- Single beam echosounder seabed discrimination systems

Sampling for ground-truthing of such systems is also addressed.

- **Pollution** - This would include a range of pollutants, each of which would require a different sampling approach:
  - Floating litter
  - Sinking litter
  - Pollution in the water column
  - Pollution in the sediment
  - Pollution in organisms
- **Environmental conditions** - principally weather conditions and sea state.

The columns provided information for each of these parameters covering:

- Relevant MSFD Descriptor
- Survey type appropriate to the collection of that data
- The preparations needed before the survey
- The additional requirements during the survey, in terms of:
  - Additional skills
  - Additional personnel
  - Additional ship time
  - Additional facilities
- The additional requirements after the survey, in terms of; laboratory facilities, equipment and software, sample and data storage etc.

In Chapter 4 we addressed a number of important implications for survey planning and conduct of any move towards EAFM surveys. This included:

- Seasonality – The impact of changes across the year and the use of a single period survey to characterize the ecosystem.
- Unfishable habitats – Most surveys and particularly trawl surveys will include large areas where bottom-trawl fishing is not possible. This would have implications for EAFM surveys and indeed for stock estimation surveys.
- Spatial resolution – This is a combination of the spatial and temporal scale of our sampling tools and of changes across the ecosystem we wish to sample.
- Wide spread v. detailed local surveys – There is value in both wide area surveys, which allow broad scale perceptions of the ecosystem, but also in small scale, local and detailed surveys that can provide much more information about process and linkage.
- Monitoring v. Process surveying – As with wide spread v. local, we can learn different things from surveys targeted on monitoring e.g. resources surveys, as well as the more detailed but local process based surveys. Both should form components of a fully integrated ecosystem survey approach.
- Stratification by habitats – Currently many resource surveys are stratified by target species abundance, although some include fish community and

depth strata. In an ecosystem approach, it will be important to representatively sample the full range of habitats.

- Use of ecosystem models to identify data or structural weakness – There should be a feedback between the surveys and the models we use to explore the ecosystem based on survey data. As well as illuminating ecosystem functioning, the models can also show us where our sampling is weaker, or where the models themselves require more data support.
- Data stream integration – Full EAFM surveys will develop a vast amount of data, collected on many different approaches, e.g. station based, transect based or integrated sampling across different ranges. Data volume will also vary, from species presence/absence binary data through to multi-beam acoustic data, and will require careful consideration of how to bring these all together clearly and coherently.
- Fully Synoptic Surveys – The best advantage from EAFM surveys will be gained where the data are collected in a synoptic fashion, coherent sampling in time and space. This represents a challenge to surveys and suggests the need for multi vessel surveys operating wither on different parts of the area or on different types of data collection. This in turn raises implications for calibration and management.
- Unused current data potential and samples – Before even addressing future elaboration of EAFM surveys, we should make better use of data that we collect already, and rarely use. For example, plankton samples taken on icthyoplankton surveys
- Data purpose and conflicts - As we move towards more sampling and analysis on surveys we will likely encounter more and more conflicts between sampling approaches, e.g. different acoustic instruments. We will also need to be clear on the purpose of the data collection and its quality requirements.
- Year of the EAFM survey - Rather than moving in an ad-hoc and incremental path towards full EAFM surveying, it may well be advised to consider dedicating one year of survey effort to a comprehensive integrated survey. This might provide the substrate for analyses into what level of sampling (in time and space) is needed, and would provide a strong baseline for future work.

Finally in Chapter 5, we provide three case studies for surveys that were designed with the EAFM as part of the survey concept. These are presented as short pen-pictures, along with references to more detailed information. The three surveys were:

- The Norwegian Barents Sea Ecosystem Survey
- The German Small-scale Bottom Trawl Survey
- The UK Western Channel Beam Trawl Survey

1 Opening of the meeting

1.1 Terms of Reference

The Workshop on Cataloguing Data requirements from surveys for the EAFM (WKCATDAT), chaired by D. Reid, Ireland, will meet in Dublin, Ireland, 26–28 January 2011 to:

a) Provide a comprehensive catalogue of the data required from surveys to support all aspects of the EAFM; including inter alia fish stock assessment, ecosystem modelling, ecosystem indicators, and process based research;

b) Provide guidance on what factors should be considered of higher priority in modifying or improving surveys;

c) Report on any implications from this exercise for the planning of future surveys.

2 Adoption of the agenda

The agenda was sent to all participants on the 21st January and adopted at the start of the meeting. It was agreed that the primary output for this workshop would be the table cataloguing the data needed for EAFM and potentially provided by research vessel fishery surveys. The participants in the WK were drawn mostly from the survey community, and it was agreed that this was not a completely appropriate group to define the priorities within the catalogue. It was agreed that the best route forward was to pass the completed catalogue to other appropriate WG, in particular WGECO, WGFE, WGME, WGSE, BEWG, WGINOSE and WGGOOFE, as well as any other interested parties for assignment of priorities. This is detailed further below.

3 Data Catalogue and priorities (addressing ToRs a) and b)

3.1 Introduction

The core aim of the workshop was to develop a comprehensive catalogue of the data needed for the EAFM and that could be provided by fishery oriented surveys. A number of institutes had been able to carry out such exercises in-house and prior to the meeting, in particular IMARES and IMR (Bergen). These were evaluated by the WK, and it was agreed that they could provide a template for development of the catalogue for this report. The basic outline comprised a series of rows detailing the main ecosystem variables, and columns indicating the issues involved in collecting such data. The main development at the WK was to extend the scope of the columns in the table, and to include all possible data collection potential in the rows. The table produced by this exercise is presented as Table 1.

The columns in the table provide information on the data to be collected, the relevant MSFD descriptor, the type of survey where it can be collected, and the additional requirements before, during and after the survey.

3.1.1 Task – Data to be collected

The data types were broken down into a number of sub-headings:

- Fish and other organisms

This would comprise all the different types of data that could be collected on or derived from the fish sampled during the survey. This would be in addition to the routine sampling carried out in the context of the survey. In particular

- Organism collection (e.g. for contaminants, fatty acids analysis etc.). Any organisms, including *inter alia* fish needed for subsequent analysis. The list is not exhaustive, but is intended to represent biological material collected from survey hauls for post-analysis.
- Stomach sampling – collection of fish (and other species) stomachs for diet data determination.
- Additional biological data (e.g. liver/gonad weight, otoliths, scales, fin-rays, length-weight data of other than standard species).
- Disease/parasite registration – Either recording disease or parasite presence, prevalence etc. Or collection of sample material from catch for post-analysis.
- Genetic information – usually removing and preserving tissue for subsequent analysis e.g. muscle samples or fin clips.
- Lipid content – of fish and other organisms.
- Sonar observations pelagic fish – Recording of pelagic fish schools using vessel mounted sonars, which are not routinely used.
- Tagging – While this is not strictly data collection, fish, and other organisms may be tagged and returned in the context of the survey.
- Bioactive materials in marine species – collection of whole or parts of organisms for post analysis for pharmaceutical or other purposes.

Physical and chemical oceanography

This would comprise all the different types of data that could be collected during the survey. This would be in addition to the routine sampling carried out in the context of the survey. In particular CTD, chlorophyll, oxygen, nutrients, turbidity, etc. This is not an exhaustive list, but essentially this type of data collection falls into a number of categories.

- Continuous underway measurements – this would be using standard systems e.g. vessel mounted thermosalinograph, but could include towed systems and undulators.
- Station measurements – This would include standard station based approaches as used for example, for CTD, but could also include water bottles and other sensors mounted on the lowered body, e.g. hydrographic carousel.
- Autonomic devices – The survey vessel acting as a mother ship for an AUV or other autonomous vehicles to collect temperature, salinity and other measurements. This could include the placing and recovery of mooring, landers etc.
- Water movement – This would include the collection of data using the vessel's ADCP or other remote current measuring devices. It would also include moorings as above.
- Nutrient samples – Using water bottles or other appropriate collections systems. This could include other aspects of water column chemistry.

Biological oceanography

This would comprise collection of plankton and other passive biological material, for instance, zooplankton, phytoplankton, nano- and pico-plankton, as well as bacteria and viruses. The collections systems would probably be complementary to those used for chemical sampling and include:

- Water samplers – e.g. bottles or similar while stopped for e.g. CTD stations.
- Continuous plankton recorders, as used in the CPR programme, to sample phyto- and zoo-plankton in the surface layers.
- Towed profiling samplers – such as the high speed samplers used in the context of icthyoplankton surveys that can be lowered through the water column while steaming. Such samplers could be relatively simple and collect one depth integrated sample, or use more complex systems that allow discrete collection at different depths.
- Dipped samplers – Lowered nets such as Bongos to collect plankton samples at a station.
- Echosounder at proper frequency – Acoustic data can be collected and analysed for the presence and intensity of the various scattering layers in the ocean. It should be emphasized that this would also need considerable ground-truthing plankton samples.

Invertebrates

This would comprise collection of invertebrate biological samples, outside the remit of the surveys principle task. The collections systems would vary depending on the type of biota targeted:

- Infauna – This would require sampling with grabs, corers or other systems, that would require the vessel to stop at a station. This includes sub-bottom profiling camera systems.
- Epifauna – could be sample either directly, e.g. with beam trawls etc. or indirectly using towed or dropped TV systems.
- Pelagic – Using nets appropriate to the target species e.g. MIK, MOCNES systems.

Megafauna

This would comprise collection of data on the type of larger species not generally sampled with fishery survey tools, for example, mammals, seabirds, large elasmobranchs. For most examples this would involve the type of sight survey approach used for cetacean and seabed surveys, but could also include the use of towed hydrophone systems to track cetaceans underwater.

Habitats

This would comprise collection of data on seabed substrate, structure and relief. Mostly this would involve acoustic seabed discrimination systems, some of which are detailed here, but also direct camera observation. A number of possible data collection systems could be utilized:

- Towed/dropped camera – TV pictures could be obtained of the seabed using either towed camera sledges, or with the TV or stills cameras mounted on a drop frame. Towed systems would provide a continuous data stream, while the dropped systems would provide point data. This information would include the physical and biological characteristics of the seabed, but not aspects like grain size.

- Side-scan sonar – This would usually be using a towed side scan system, and would provide information on the surface texture and relief, some of which could be interpreted in terms of substrate and habitat.
- Multi-beam echosounder – Multi-beam acoustic systems are available now on some RVs. These provide similar output to the side scan systems, and can be operated underway.
- Single beam echosounder seabed discrimination systems – These are signal processing systems that use characteristics of the seabed return to discriminate the substrate of the seabed. Examples include RoxAnn and Quester Tangent systems. These can be operated underway.
- Ground-truthing – All such remote acoustic approaches require additional ground-truthing data to confirm diagnoses of the seabed type. These would usually involve grabs and corers, and other direct sampling approaches.

Pollution

This would include a range of pollutants ranging from large objects or litter, through to chemical pollutants in water, substrate or organisms. Each would require a different approach on the survey:

- Floating litter – This would be any material on the surface, and would be best sampled by some form of surface trawling.
- Sinking litter – This would be expected to collect on the seabed, and would be best sampled with trawls or similar gears, but could also be charted with TV systems.
- Pollution in the water column – This would be sampled with same types of approach used for the chemical oceanography sampling, and could be underway or on station.
- Pollution in the sediment – This would require samples to be taken with grab, corer etc. on station.
- Pollution in organisms – This would require similar sampling approaches to that used for fish diseases etc.

Environmental conditions

This would largely comprise weather conditions and sea state. These are generally collected by the bridge crew on the RV. However, they may often not be recorded in a format useful to ecosystem research, and this is a data source that is often underexploited.

3.1.2 MSFD Descriptor

Each data type was assigned to the relevant category from the MSFD descriptors.

The descriptors are defined as follows:

nr	descriptor
1	biodiversity
2	non-indigenous species
3	commercial fish and shellfish
4	foodwebs
5	eutrophication
6	seabed integrity
7	hydrographical conditions
8	contaminants
9	food safety
10	litter
11	energy and noise

3.1.3 Survey Type

This column describes the type of survey on which the ecosystem data described above could be collected. Four main categories of survey were defined. These were:

- **Trawl surveys** – This could include bottom-trawl surveys using otter trawls or beam trawls and possibly dredges. It would include all the major ICES international trawl surveys. These are essentially station based surveys, where additional sampling would primarily occur at the stations, although there would be some scope for underway data collection between stations. The trawl is not an ideal platform for additional sampling gear, and so any such additional deployments would have to be carried out using extra time on station. Additional station based data between the standard stations would represent a major change in the survey.
- **Acoustic Surveys –** These are primarily based on continuous underway surveying with echosounders or similar equipment. Trawling is carried out, usually mid water, and usually on echotraces seen on the echosounder for which a species ID is required thus at locations not known in advance. Their key advantage is that the transects are generally systematic and designed as an underway survey. The addition of various underway samplers e.g. towed samplers such as CPR or undulators would be reasonably easy. Additional stations would represent a major change in the survey.
- **Icthyoplankton surveys -** These are primarily station based surveys which collect plankton samples at station either underway (usually at reduced speed) or using vertical dips. Stations are usually placed in a regular grid, and so, between station transects? Have many of the advantages of the acoustic surveys. The stations will often be relatively easily adapted to collect a range of additional data, particularly for physical, chemical and biological oceanography. Samples of organisms other than plankton would be

less easy. Additional stations would represent a major change in the survey.

- **TV surveys –** These are mainly based on stations where a TV sledge is towed at slow speed over a short distance. They would be most useful where additional interpretation of the TV data were required, e.g. for habitat or additional macro-benthos species. Due to their nature, any additional sampling would require additional equipment and time.

3.1.4 Preparations needed before the survey

These columns indicate the additional requirements for this type of sampling before the survey. This would mainly be considering the needs for additional equipment and skills.

3.1.5 Additional requirements during the survey

For each survey type, we assumed that the standard resources for such a survey would be on board and available for any additional work. In this case, no additional gear, skills or facilities would be needed. This column then concentrated on what additional resources would be needed to collect a particular type of ecosystem data.

- **Additional skills** – This would be where the standard skill set of a survey team would not routinely include that needed to collect the additional samples or operate the technology. In many cases this would imply a training need, however, in some cases it would require an additional person.
- **Additional personnel** – This would be where the task represented a significant increase in the work required to the level where it would carry a risk of compromising the core work on the survey. Under such circumstances additional staff would be needed. In many cases, we have identified particular sampling tasks as not requiring additional personnel. This is predicated on that being the ONLY additional sampling task. It should not be assumed that the survey team could be asked to take on twenty such additional tasks, without additional personnel.
- **Additional ship time** – This column is to differentiate between those tasks which could be carried out simultaneously with the standard tasks for that survey. E.g. cetacean counting on an acoustic survey, or additional chemical instruments on a CTD carousel. Many additional tasks will require a longer time spent on station to carry out an additional sampling routine e.g. benthic beam trawling at bottom-trawl survey stations. In some cases these task could be carried out during programmed downtime. Many surveys do not operate at night, and this time could be used for additional sampling, usually with a need for additional personnel (possibly also for the crew).
- **Additional facilities** – These would mostly comprise of laboratory facilities and equipment not normally taken on that type of survey, as well as additional storage facilities.

3.1.6 Additional requirements after the survey

Again, for each survey type, we have assumed that the standard resources for such a survey would be available on return. These columns then concentrated on what additional resources would be needed to deal with a particular type of ecosystem data after the survey. These included additional laboratory facilities, equipment and software, sample and data storage.

3.2 Priority setting between categories of data collection

It was hoped to set an initial prioritization as part of the workshop, however, the participants felt that the group was more focused on the planning and conduct of the surveys rather than the use of the data delivered from the surveys. While prioritization may have been possible, it was agreed that it would be better to have this done by a different group with a focus on the use of data rather than the collection of it. In this context, the WK identified a number of key groups, including WGECO, WGINOSE, WGFE, WGME, WEGSE, BEWG, WGOOFE and others. It is proposed to pass the table to these groups, and request that they apply priorities based on their perceptions of the data needs for the EAFM. We have proposed three additional columns to the table.

Priority

- 3 – primary
- 2 – important
- 1 - desirable
- 0 – not needed

Rationale

- Brief description of why the priority has been assigned at this level, and what it would be used for.

Accuracy, precision and resolution issues

- Brief description of the degree of accuracy and precision required in the data, possibly including the positioning of samples, i.e. random locations or adopting the often fixed sample locations of trawl surveys. This should also include the optimal spatial and temporal resolution of the samples. I.e. would samples taken at IBTS trawl stations be useful, or would there need to be more stations.

4 Implications for the planning of future surveys (addressing ToR c)

4.1 Introduction

A second aim of the workshop was to explore and document some of the implications for the existing surveys of moving to a more EAFM approach to data collection. During discussion a number of topics were raised and these are briefly discussed here.

- Seasonality
- Unfishable habitats
- Spatial resolution
- Wide spread v. detailed local surveys
- Monitoring v. process surveying
- Stratification by habitats
- Use of ecosystem models to identify data or structural weakness

- Data stream integration
- Fully Synoptic Surveys
- Unused current data potential and samples
- Data purpose and conflicts
- Year of the EAFM survey

4.2 Seasonality

Seasonality is a fundamental aspect to consider meeting the goals of an ecosystem approach to fisheries management. Seasonality is characteristic of temperate environments and implies the occurrence of key season-specific ecological, biological and oceanographic processes that could be masked if the data are collected at the wrong time of the year. Several research surveys are performed in determined seasons of the year which are not necessarily relevant to the study of all key ecological processes. For example, a survey in Quarter I (winter) or Quarter IV (autumn) will not allow collecting relevant data on phytoplankton spring bloom or on the following zooplankton bloom. Zooplankton is acknowledged for instance to have a crucial impact on fish larval survival and recruitment as well as fish food intake and growth. On the other hand, a survey in Quarter I could be used to collect winter nutrients data, known to have an impact on spring phytoplankton production. Another example is constituted by migrating species, whose different seasonal movements (open sea-coast, in-out migrations from the survey area) make very difficult to follow their life histories for a research survey fixed in time and covering the same area. Finally, organisms' feeding intensity could be concentrated in specific seasons and therefore stomach analyses, if considered important, should target these periods. Therefore, a careful examination of the timing of ecological, biological and hydrological events must be done to decide what are the relevant data that can be collected during a specific survey.

A way for overcoming the limited seasonal coverage of research surveys could be the use of commercial vessels or additional sources (e.g. ferry boats for hydrological or Chl a measurements) increasing the temporal resolution of the information collected throughout the year. This would be very useful to detect potential phenological changes and their impact on ecosystem function.

4.3 Unfishable areas

Conducting a survey is subject to the suitability of the chosen location for the method or methods applied. Use of multiple methods required to collect data for the 'ecosystem approach' runs the risk of only collecting a subset of the desired information. Unsuitability of a selected site for a particular technique results in problems with the integration of datasets and the interpretation of results. In particular, the deployment of sampling equipment which interacts with the seabed, such as fishing nets, TV sledges and umbilicals, or benthic grab samplers, depends upon the suitability of the substrate to that particular sampling gear. It occurs regularly that samples are not collected due to concerns over damage to equipment.

It is useful to make the distinction between (1) sites where data may be collected but sampling is not carried out due to the risk of gear damage, for instance trawling over an area of bedrock to sample the fish fauna, and (2) occasions where a sample is not collected because a given method will not produce a meaningful result, such as attempting to grab for infauna at the same site. The first instance represents a deficiency in survey methodology – it would be possible to sample the fish community in an untrawlable area through the use of alternative means, such as traps or longlines. The second case represents a failure in survey design – it is not possible to collect infaunal data at such a site as it does not exist in any meaningful way. An additional variation of the theme is a station selection, where in principle the survey is based on randomly selected stations, but where in certain areas (e.g. ICES rectangles) only one or a few fishable positions exist. Either way, care needs to be taken over interpretation of data and sampling effort should not be simply relocated to the nearest suitable location without recording a foul station at the intended site.

Furthermore, areas can also be considered closed to sampling due to reasons of technical or ecological protection, such as the exclusion areas surrounding oil rigs or around vulnerable marine environments. In the case of VMEs, TV equipment which "flies" over the seabed may be used in the latter case.

Finally, areas can become inaccessible to a given method when conflicts arise between different methods, for example between marine mammal/seabird observation and fishing activity. For marine mammals the observation protocol commonly requires a one-hour delay between the end of fishing operations and the start of observations to minimize the aggregating effect caused by discarding of catches. Such an issue requires better survey design, for example deploying observers on boats which are engaged in more benthic or acoustic sampling.

4.4 Spatial scale and resolution of observation

It is important to realize that our ability to observe and describe components and processes in an ecosystem depends both on the scale of the natural variation itself and the resolution of our observations which is method depended. Therefore, the interplay between the objectives of the survey, the scale of the natural variation, and the resolution of the observations, must be considered when planning the survey and in the subsequent analyses. The objectives should specify the appropriate or required spatial and temporal scale of the information obtained from the survey.

4.4.1 Natural spatial variation scale

The scale of the natural spatial variation differs widely between ecosystem components and processes, spanning from localization of a single component (cm), through patches of components (m), habitats (m-km), geographic distribution area (km) to the whole ecosystem or even large ocean systems. An example is the contrast between predator–prey interactions among plankton on a scale of cm vs. occurrence of different water masses on a scale of several km. The ecosystem survey conducted in the English Channel (see Section 5.3) serves as an example of how spatial scale might be considered to determine the proper observation resolution. Note that when the different components of the ecosystem interact, their spatial covariation may vary with scale and that they can influence each other's scale of spatial variation. For example, the spatial correlation between a predator and prey might be high at small scale due to direct interaction, low at medium scale due to predator avoidance, and higher again at larger scales due to predator aggregation.

4.4.2 Observation resolution

Observation resolution varies widely between different gear, technology and the way they are used. Examples are water samples with a resolution of cm^3, a bottom-trawl sweeping a corridor several meters wide and several 100 meters length, and satellite observations of phytoplankton at with resolution of several km. It is important to distinguish between observation resolution and observation range or coverage. Echosounder observations ideally have a resolution of one ping, but the range are several km along the cruise lines. The transect-based resolution could be on the scale of 100 m. Thus, a fine resolution method may provide information about large-scale variation. Note also that some methods aggregate the variation over a certain scale, thus masking the natural variation at smaller scale, e.g. a trawl haul.

4.4.3 Evaluation of spatial scale

To evaluate the relationship between scale of spatial variation and observation resolution it is necessary to collect data at highest resolution possible with high level of coverage. This enables quantification of the spatial variation of ecosystem components and processes at all relevant scales. Ordinary monitoring data rarely meet these demands, as they often are of a low resolution compared to the natural scale of variation. Those data supply important information about the variation at larger scale. On the other hand, small scale process studies are important, providing complementary information at smaller scales for evaluating survey performance related to the scale of spatial variation. In addition, these surveys often provide local replication, which is crucial to studying the occurrence of rare species, the local variation of all parameters considered, as well as real observations of the temporal variation at a location. The German small scale trawl survey in the North Sea described in Section 5.2., serves as an example.

Proper quantification of the scale dependent variation of ecosystem components and processes enable evaluation and planning of the survey methods and the relevant resolution for the variables of interest. Depending on the survey objectives, a variable varying on small scale needs a finer observation resolution compared to more spatially homogenous variables.

It is also important to note that the ability to observe the natural scale of spatial variation also depends on temporal variation and its scale. The temporal scale or resolution refers to the time frame for the variation or the time-steps of observations (e.g. daily, monthly, year-to-year). Thus, the mobility of organisms is an important confounding factor that should be considered when evaluating effects of spatial variation scale.

4.4.4 Time and space scale variation matrix

One approach to assess the scale problem when observations of high resolution are unavailable is to sort the different ecosystem components and processes according to their scales of variation in time and space based on auxiliary information. The information is presented as a time/space matrix representing a map of the different scales of variation (quick vs. slow and close vs. distant) in the components and processes. The variables can then be sorted along these axes. This enables evaluation of the dynamics in e.g. long-living benthos organisms compared to short-lived pelagic fish species. Based on this knowledge it is possible to make recommendations about the frequency and scale of observations in time and space needed to describe the temporal and spatial variation, and how often this must be updated related to the natural dynamics of the component or process. This can in turn be used to provide guidelines about for which survey activities the sampling in time and space can be reduced, and for which it must be increased.

4.5 Wide spread vs. detailed local surveys

Data from small scale Ecosystem Approach surveys can be used to compliment large-scale stock monitoring surveys, meeting more of the needs of the Ecosystem Approach to Fisheries Management (EAFM). The majority of survey time for European fisheries institutes is spent on stock monitoring surveys. This is a massive resource, which collects data on more than just the species that are used for assessment. The International Bottom Trawl Survey (IBTS) provides a long-term monitoring of groundfish communities on the large-scale: it covers the entire North Sea with the grid of ~ 30 x 30 nm ICES rectangles, and a time span of several decades. This scale and resolution offers information on several aspects of the ecosystem: First, data needed for stock assessment of commercially fished demersal species. Second, IBTS provides hydrographic data, and at the same time the observation of long-term biological development in the North Sea overall. These data are being used, e.g. to look at the sea-wide shifts in species distribution patterns over time.

Different spatial scales need to be considered when looking at processes and patterns of change that occur locally, i.e. within the range of a few nautical miles. Examples for these are local overlaps of predators and prey, the association of fish assemblages to habitat types, or local shifts in species composition of fish assemblages. With this perspective and linked to their commitment to the IBTS, Germany carries out a small scale survey whilst participating in the North Sea IBTS in Q3 (Ehrich *et al*., 2007 and Section 5.2). The information collected during the so-called German small-scale Bottom trawl survey (GSBTS) is combined with records of several additional ecosystem components. The data collection is labour and ship time intensive. The survey covers twelve “box” sites, which takes a total of 36 days of ship time to sample. During this time, ~252 otter trawl stations, 180 hydrographical stations and 108 2m beam trawl stations for epibenthos are carried out. Obviously, the high spatial resolution can result in a higher total number of hauls per day of ship time, as less steaming time between stations is needed. At the same time, it would not be possible to sample with the intensity of the small scale survey over the larger areas used for stock monitoring surveys, and the location of such “boxes” should be chosen to represent the water body relevant to the studied processes.

Due to the high effort involved, small-scale surveys cannot be conducted at a spatial coverage used for fisheries management purposes, i.e. to produce robust indices used in stock assessment. On the other hand, they can provide process understanding as well as monitoring of sampling-intensive parameters, e.g. biodiversity of fish assemblages, which needs a minimum number of hauls to be able to include rare species. These survey sites may also be used to focus on the processes affecting the habitats, something that again could not be possible if tried on the larger scale alone. In order to make the most of the small scale surveys, areas that are sampled should be selected that are representative of the different habitats of the larger area.

The question, of which type of survey is more useful for the EAFM, depends on the objective, e.g. a specific survey with respect to the EAFM. Ultimately, no single survey is likely to meet all the needs of the EAFM; however it is possible that a combination of surveys could do.

4.6 Monitoring vs. Process Surveying

Monitoring and process study based surveys address different questions. Data collected during both types of surveys are relevant within the EAFM context but often do not measure the same parameters or follow similar sampling protocols at equal space and time-scales.

DCF surveys are part of regular monitoring programmes that have standardized sampling designs and are carried out periodically (e.g. annual or triennial). On the other hand process study surveys aim at answering particular questions and the spatial and temporal scales are adapted to the problem at hand, process study surveys usually do not run as long time-series. The results of process studies should be useful for helping defining which data to collect in monitoring surveys, in particular in the framework of the MSFD.

Particular processes can be studied opportunistically during monitoring surveys when time and space scales are appropriate.

Important local processes (e.g. mesoscale hydrographic features) could be highlighted. Sampling for its assessment could, when possible, be included in the regular monitoring surveys.

Modelling approaches have the potential to integrate information originated from monitoring and process study surveying (see Section 4.8).

4.7 Habitats and Survey Stratification

Stratifying sampling by habitat improves our understanding of ecosystem functioning and increase precision of ecosystem indicators. The underlying assumption is that ecosystem interactions are characterized by the physical and chemical characteristics of the arena in which they occur and that all areas of an ecosystem can be attributed to a unique combination of such characteristics (habitat). Understanding the processes within a habitat as well as the transfer of energy/resources between habitats will ultimately determine ecosystem functioning. As a result, careful consideration needs to be given to capture these effects when designing new surveys or altering existing surveys to deliver advice on ecosystem status.

In reality, ecosystems are characterized by gradients of physical, chemical and biological gradients rather than unique easily identifiable combinations of conditions. Dividing these gradients into appropriate partitions is highly dependent on the severity of the gradients as well as the ultimate aims / required precision that a survey is expected to address (see section on spatial scales). Furthermore, the ecosystem components to be monitored (gear section), instrumentation precision (incompatible data section) and practical survey operational requirements (available ships time) will need to be taken into account when determining the number and extent of strata and the appropriate survey design (fixed station vs. random stratified).

Ideally, within a stratum physical and chemical conditions are reasonably stable over periods of decades. Only then, changes in the biological components can be easily detected and might be characterized as a response to anthropogenic alterations. However, it will be difficult to distinguish those changes from alterations to the physical and chemical conditions or from random fluctuations in the biological system. Derivation of appropriate strata requires data of a greater spatial and temporal resolution than is ultimately required for monitoring. We have developed some multivariate and bootstrap methods based on fish abundance information from the fixed station designed UK Irish Sea beam trawl survey (ISBCBTS) to determine the number and spatial extent of strata. Indications from a truly multidisciplinary research project conducted on the random stratified survey designed Western Channel beam trawl survey (Q1SWBeam, see Section 5.3) suggest that strata developed in such a way may be suitable to monitor other ecosystem components although considerations of the survey area, ultimate aims and the indicator precision needed for the monitoring program require that these methods be assessed on a survey by survey basis.

The MSFD specifically requires the development of habitat definitions in order to assess GES1-Biodiversity. Sampling on the scale of the habitat or implementing these as strata is therefore important in order to ensure that all habitats are sampled adequately to evaluate the GES indicators at the required level of precision.

4.8 Use of ecosystem models to identify data or structural weakness

Ecosystem models can be used for informing decisions on what to sample at sea. Ecosystem models have become a standard tool for investigation the potential usefulness of indicators for the ecosystem approach to fisheries management (e.g. Fulton *et al.*, 2005). The same ecosystem models can also be used to determine which ecosystem components might be important for example in terms of biomass fluxes, representing crucial pathways or being sensitive to human impacts. Further, when parameterizing these models the major data uncertainties become evident. Thus both the so called parametric and the structural model uncertainty are informative in terms of which components and processes are crucial but uncertain and hence which data would be most informative. Most likely the resulting list of parameters to be sampled at sea will be region dependent.

4.9 Data stream integration

4.9.1 Data collection and sharing

The data from ecosystem surveys collecting a range of information should be available to all parties involved in the survey. Only in this way, it will be possible to integrate data. In order to facilitate data exchange, it is highly recommended to agree on an exchange format before the survey takes place. In addition, it should be clear to all participating parties who would be responsible for specific datasets. If the purpose of a survey is to combine different data on a spatial scale, there should be clear agreement about the numbering and naming of the stations. This will facilitate spatial data integration even if data are not collected at exactly the same location (see also Section 4.4). It should be made clear that data collected at the same time and location, may not necessarily be correlated, for example due to different spatial and temporal scales of the underlying processes, or because parameters are not correlated at all.

4.9.2 Data exchange and metadata

Data exchange and valid use of the collected data requires a clear data description (metadata). Apart from the standard metadata information (e.g. via EDMED, CSR, etc.) the metadata should give information on the data collection purpose (also see Section 4.12) and the data collection method. By supplying this information, the user should be able to identify whether or not the data might be suitable for the analysis.

4.10 Towards the fully synoptic survey

The analysis of ecosystems, their status and development based on ecosystem surveys will be improved if the parameters are measured synoptically (ideally at the same spatial and temporal scale). Especially in highly dynamic environments, temporal differences in the sampling of different ecosystem components may hamper proper analysis, especially for process related investigations.

Unfortunately, the needed resources, such as vessel time and analysis capacities, are limited. Therefore, an essential task in planning and conducting ecosystem surveys is to find ways to improve the survey design and survey work to allow as close to synoptic sampling regimes as possible.

At least, two approaches are possible, involving either one vessel carrying out all the tasks, or multiple vessels and/or platforms sharing tasks or areas.

4.10.1 Multiple tasks – possibly compromising the survey

Surveys are usually designed in order to fulfil specific objectives (e.g. indices of abundance, species spatial distribution and so forth). As already mentioned, with the introduction of the ecosystem approach concept there has been a general tendency to increase the amount of data to be collected during the already existing surveys.

However, the collection of ancillary and essential data may sometimes be incompatible. In the attempt of broadening the tasks of a survey and collecting the highest amount of data one may in fact obtain confounding results which may compromise the primary aim of the survey and complicate the interpretation of the outcomes. As an example: if we are investigating a migrating species, we may overlook this spatial segregation if we concentrate the resources on a single temporal scale. We may risk obtaining in this way biased information on the population structure.

4.10.2 Multiple vessels (e.g. in parallel)

Depending on the extent of the intended additional data collection, needed for ecosystem based analysis, it might be that the available resources on one vessel (available time and staff, structural preconditions of the vessel) are not sufficient to match requirements. Additionally, in some cases the requirements of different sampling strategies may not be compatible with each other and would hamper single vessel synoptic sampling.

Task sharing between vessels could be a solution around this problem, where:

- the different sampling approaches are shared between vessels
- the area to be sampled is shared between vessel and similar data are gathered on the vessels
- or some combination of both

Multi-vessel surveys are often conducted in the context of stock estimation surveys and have a number of advantages and disadvantages (see Table 4.10.1)

Table 4.10.1. Overview of the pros and cons of different multiple vessel survey-strategies.

	A) SHARING OF SAMPLING	B) SHARING OF AREA
when to choose	> if vessels have different skills > incompatible sampling strategies (e.g. transect vs. station work) > if highly dynamic ecosystems require fast sampling of ecosystem components to be synoptic as much as possible	> if different vessels are able to conduct sampling > typically chosen for internationally coordinated surveys
efficiency	- each vessel has to work on the entire station grid, which results in more steaming time compared to option b) + each vessel has specific sampling equipment	+ efficient sampling due to reduced steaming time (for each vessel the station grid is significantly reduced) - all sampling equipment is needed on each vessel

	A) SHARING OF SAMPLING	B) SHARING OF AREA
required staff	+ less demand for highly specialized staff, because only specific sampling approaches are conducted on each vessel	- each vessel needs specialized staff for all sampling approaches
data quality	+ no intercalibration between vessels needed	-calibration between vessels needed

4.10.3 Intercalibration

Almost any kind of sampling requires the calibration of sampling equipment (sensors etc.) and sampling procedures to meet required accuracy. In addition to these standard calibration procedures, multi-vessel-surveys should include some intercalibration between vessels. This procedure is already carried out for standard multiple vessel surveys, such as internationally coordinated fishery surveys (e.g. IBTS).

Based on the intercalibration, potential vessel effects can be investigated and used to improve survey design, standardization, data quality and the value of the analysis.

4.10.4 Use of commercial vessel/ships of opportunity

Research vessels have significant advantages and are generally designed as multi-task research platforms. Nevertheless, they are expensive and scarce, their utilization for widespread (space and time) data collection is often limited due to the restricted number of vessels and hence vessel time available.

An alternative, only partly considered in the past, is the use of commercial vessels/ships of opportunities (called hereafter cv/soo). There are two general possible applications of cv/soo:

a) to contribute to a multi-vessel-survey (see details there) carrying out specific tasks

b) to be the basis for an own dataseries.

Usually, for option b) the selected vessels operate frequently in specific areas. Hence, this is an excellent basis for the establishment of a dataseries with high temporal resolution, compared to scientific surveys often conducted on an annual basis.

Beside this indubitable advantage, cv/soo are not research vessels and the availability of experienced staff for sampling is mostly limited, also for installation and maintenance of any observation system or technology and for later analysis of the data. Consequently, there are specific needs to be matched concerning sampling equipment (highly automated) and sampling protocols (as easy as possible). Nevertheless, the quality of data sampled using cv/soo is often lower, compared to those collected on research vessels. This potential lower data quality has to be taken into account for analysis, but the amount and frequency of data may compensate for this.

Potential applications for Option b) would be:

- use in commercial fisheries observation (often called reference fleet)
- use on vessels on regular routes (ferries etc.). Some examples where this approach was successfully established and delivers very important long-time data are:
    - Continuous Plankton Recorder (CPR) Surveys, http://www.sahfos.ac.uk/
    - FerryBox-approach, http://www.ferrybox.com/

4.11 Unused current data potential and samples

Many of the existing surveys within the ICES world already have the potential for substantially contribute to the ecosystem approach. In many instances, observations and/or samples collected during existing surveys may be only partially processed and analysed or, perhaps, not processed or analysed at all. These collections should be archived (or preserved) and catalogued because they may turn out to be important sources of information for ecosystem research.

For instance, samples collected during ichtyoplankton or egg surveys are usually analysed only for the target species and not analysed further as the analysis of plankton samples is very time consuming. Examples are the herring larvae surveys (ICES 2010) or the mackerel and horse mackerel egg survey (ICES 2009). In case of the mackerel and horse mackerel egg survey, samples are collected triennially along the continental shelf from Portugal to the Faroese islands during numerous research cruises carried out between January and July. The coordinated further analysis of these samples could provide valuable ecological information, particularly for zooplankton. The use of automatic image analysis systems (e.g. ZooScan – Gorsky *et al.*, 2010) might enable a systematic analysis despite of restricted funding.

Another example is the collection of hydrographic data which are often only used partly, as the probe is equipped with more than the necessary sensors for the target investigation.

Backscattering data collected during acoustic surveys of midwater fish stocks may be also particularly valuable. Multi-frequency acoustic systems which are now installed on many research vessels can provide backscattering data for a broad size spectrum of animals and may also be useful for habitat characterization. Researchers should be encouraged to collect, record, and analyse acoustic data for the full range of frequencies available, and to calibrate for each frequency. Ground-truthing should also be enhanced were possible so that all sources of scattering can be identified.

4.12 Data purpose and conflicts

One of the key problems associated with developing integrated ecosystem surveys is that of conflicts between the different types of data collection that are likely to be collected on such surveys. This applies first in terms of the physical act of carrying out the sampling e.g. the different requirements for seabed grab sampling, trawling and underway acoustic surveying. Essentially, in many instances, the vessel will have to stop doing one thing before starting another. While many activities can be carried out simultaneously, many cannot. Second this applies to the differences in the frame of reference within which the sampling is carried out. This can range from point samples (e.g. grabs) to data integrated over considerable distances e.g. plankton tows during ichtyoplankton surveys.

Table 4.12.1 summarizes some of these differences and conflicts.

Table 4.12.1. Differences in sampling approaches for a range of activities that could be envisaged within an integrated ecosystem survey.

Device	Sample Type	Analysis/Parameter	GES Descriptor	Scale of Operation	Gear Resilience (weather / habitat)	Deployment conditions	Conflicts (vessel dependent)
NIOZ corer or other grabs	Sediment	PSA, Nutrients, Chlorphyl, Contaminants, Oxygen, Infauna, Meiofauna	1,4,5,6,8	10s of cm's	MEDIUM	soft to medium sediments, trouble sealing off sample in coarse sediment, not deployeable on hard ground.	interference of vessel positionning system with acoustics
SPI (camera)	Image	Redox Profile, biota, PSA equivalant	1, 4,5,6,7	10s of cm's	MEDIUM	soft to medium sediments, trouble sealing off sample in coarse sediment, not deployed on hard ground. Some difficulty with flash functioning	interference of vessel positionning system with acoustics
Video (drop)	Video	Habitat type & variability	1,4	10s of m's	MEDIUM - HIGH	most weather conditions and in all but the most turbid waters	interference of vessel positionning system with acoustics
CTD, rosette	Water	Oxygen, T, S, Chla, Nutrients, Contaminants	1,4,5,6,7,8	10s of cm's, depends	MEDIUM - HIGH	most weather conditions	
Bottom trawls	Fish, shellfish, invertebrates, litter	Biomass, Count, length, otoliths	1,2,3,4,(8),10	1s km's	HIGH	almost all weather and most habitat types encountered. Some problems with heavy benthos catches and rocks damaging net	
Acoustics	single, multibeam, multifrequency,...	Bathymetry, Pelagic, benthic backscatter	1, 3,4,6	10s of km's (higher resolution)	HIGH although data quality suffers in shallow waters and rough seas.	might need expert to monitor equipment full time	not possible during stations due to interference ; pelagic trawl might not be deployable in addition to bottom trawls
Camera (transect)	Video	Community, Sediment, habitat	1, 4, 6	100s of m's	VERY – LOW	fine weather, but might need expert and significant alterations to cruise plan to work around weather	
Observer	Census	Marine Mammals, seabirds	1,4	1s of km's	LOW - MEDIUM (not at night)	might not work well if sampling protocol restrictis observations to > 4kn speeds, light and at least 1 hour after fishing	

4.13 Year of the EAFM survey

As described in Sections 3, and 4.1–12, there are many issues to be resolved before we can make the transition to fully integrated EAFM surveys. The approach that has generally been adopted in the past has been to add ecosystem components to existing fisheries surveys on an ad hoc basis. However, some surveys have been designed from the bottom up to collect appropriate data on the key aspects of the ecosystem linked to the primary fishery target species. Examples of this approach would include the Norwegian Barents Sea Ecosystem Survey, and the UK Channel Beam Trawl Survey (detailed in Sections 5.1 and 5.3).

One approach that would have potential to allow us to develop EAFM surveys in a short space of time would be to dedicate a particular year of survey effort to just this type of survey. The approach could be designed to cover all of the issues raised above. For example, we could carry out surveys across the year to provide perspective on seasonal changes. We could sample the ecosystem variables at high intensity and then determine the appropriate levels of sampling for an ongoing programme. We could determine what combinations of vessels would be best suited to the work, etc. The key advantage of this approach is that it would allow us to make judgements on issues like sampling intensity, precision, accuracy and timing, stratification etc based on possession of as complete a dataset as possible. Subsequent surveys could then be based on a rigorous analysis of what is actually needed to carry out such EAFM surveys and deliver the right information at the right scales. Hopefully, this would require less survey effort than in the dedicated year. Such a survey should include sufficient sampling to provide continuity in the pre-existing time-series of data including, *inter alia*, fish stock estimates and hydrography. An added advantage of this approach would be that we would also have one year where we obtained the best possible synoptic snap shot of the ecosystem, and this could always be repeated at some future time.

A substantial annual commitment is made by many countries in terms of vessels, personnel and resources for fisheries surveys. Redeployment of some of this effort would have the potential to allow us to immediately start running fully integrated ecosystem surveys, integrated both in terms of the science, and the resources.

5 Examples of developing Ecosystem Surveys

A number of surveys are now being carried out which aim at a much wider scope of ecosystem sampling than on most fishery focused surveys. We have provided examples of three such surveys;

- The Norwegian/Russian Barents Sea Ecosystem Survey
- The German Small-scale Bottom Trawl Survey
- The UK Western Channel Beam Trawl Survey

The surveys are very different in practice and concept, but all illustrate many elements of what would be needed for any future ecosystem focused survey. For each survey we have included sections on:

- The main purpose of the survey
- The aspects of ecosystem investigated, and potential indicators supplied with data.

- Lessons learned while developing these surveys that would be relevant to future ecosystem surveys
- Some information on the survey method along with details of where to find out more.

5.1 Barents Sea ecosystem survey

5.1.1 Main purpose

The Barents Sea ecosystem survey is a multi-purpose survey, and therefore, the main purpose is difficult to discriminate. The various purposes include elements of research, monitoring, and fish stock assessment/advice. These are described below.

5.1.2 Aspects of ecosystem investigated, potential indicators supplied with data

Important aspects investigated include:

- An acoustic capelin stock size estimate for stock assessment and management purposes
- Abundance indices for several other species of benthos, plankton and fish, to study various ecosystem processes. Some of the time-series recorded, for instance for cod, herring, polar cod, and haddock are currently used, or are considered for future use, in stock assessment
- Biological characteristics of individuals belonging to several species; length, weight, sex, maturity, age etc.
- Monitoring of geographical distribution and abundance of several ecosystem components over a number of years, to study for instance climate effects on species distribution
- Monitoring of bycatch of benthos in bottom-trawl hauls
- Monitoring of environmental conditions, like temperature, salinity, and pollution
- Synoptic observations on several ecosystem components, to study for instance trophic links and interactions among various species and between biota and the environment

5.1.3 Lessons learned

The survey has been carried out every year since 2004, and is intended to be continued. The lessons learned so far include:

- The integration of investigations that rely on sampling at fixed stations (like trawl surveys, hydrographic surveys, plankton surveys etc) and investigations that rely on sampling along cruise tracks (like acoustic surveys, observations of sea mammals and seabirds etc.) is difficult. Too long time spent on stations may compromise the reliability of the continuous surveys, because of possible migration of fish, seabird attractions to trawl hauls etc., as well as the intention to sample the whole area synoptically.
- The planning of surveys with so many stakeholders involved is a big challenge. The fact that this particular survey has been managed in slightly different ways from year to year adds to this difficulty.
- The space on board the vessels, and the kind of equipment the various vessels can operate on a continuous basis set limits as to what can be done. Because many investigations need specialists on board to do the sampling

and possibly the analysis of the data, the numbers of berths eventually sets the limit for how many different investigations can be conducted. Even the most well-equipped research vessels can at maximum apply three or four different trawls without the need for time-consuming re-rigging between the hauls. Large equipment like boxcorers, MOCNESSes etc. are difficult or impossible to handle on all but the largest vessels.

- The various sampling programs conducted during such surveys should be deeply rooted in the organizations organizing the survey. In some cases, the part of the work that has to be done after the survey (like working up age samples or stomach samples in the lab, undertaking quality assurance of all data recorded) has been lacking because manpower and money for this activity were not allocated to this kind of work.

5.1.4 Survey Method

SPATIAL SCALE	THE WHOLE ICE-FREE PART OF THE BARENTS SEA IS COVERED
Sampling scheme	The survey is carried out with 4–6 vessels from Norway and Russia on an annual basis, starting in mid-August and ending early in October. The number of ship-days have been reduced from about 120 in 2004 to about 80 in 2010
Selection of stations	Stations are fixed, and set out in a regular grid. Distance between stations are 30–35 nautical miles
Main gear	Several gears are used, see table below
Parameters/ data taken	Several parameters are recorded, see table below
Additional sampling realized	Every year additional sampling is done, based on requests from students, from scientists at other institutions etc.

GEAR[1]	DATA	COMMENT
Bottom trawl (Campelen)	Fish and epibenthos	
Benthos trawl (Sigsby)	Epibenthos	Not every year
Benthos sledge	Epibenthos	Not every year
Box corer	Sediments and infauna	Not every year
Grab (various types)	Sediments and infauna	
Pelagic trawl (Harstad)	Capelin and 0-group	In 0-group hauls the trawl is towed in predefined depths
Pelagic trawl (Åkra)	Herring, blue whiting etc	Not all vessels, not every year
Pelagic trawl (Krill)	Large zooplankton	Not all vessels, not every year
MOCNESS	Zooplankton	Oblique hauls
WP II	Zooplankton	Vertical hauls
Phytoplankton net	Phytoplankton	Vertical hauls
Secchi disk	Secchi depth	
CTD sonde	Salinity and temperature profile, optional oxygen	
Water bottles	Water chemistry, pollutants, phytoplankton	Attached to CTD sonde

[1] This list is not complete, but includes the most frequently used gears/means of data collection.

GEAR1	DATA	COMMENT
Meteo station	Air temperature, light, wind direction and speed	Continuous recordings
Echo sounder Split-beam multifrequency	Echo recordings of fish and plankton	Four frequencies sampled on most vessels
Echo sounders Multibeam	Bottom mapping	Only on one vessel
ADCP	Current profiles	Two frequencies. Not all vessels
Observers	Sea mammals, seabirds, litter floating at the surface	

Reference for methods

Survey reports are published in the “IMR-PINRO report series”, which can be found at http://www.imr.no/publikasjoner/en under “Other reports / IMR-PINRO reports” on the right side of the page. The last report (2010-survey) is no 2010–4 and can be downloaded directly from http://www.imr.no/filarkiv/2010/12/imr-pinro_2010-4_til_web.pdf/en (11.0 Mb).

These reports explain how the survey is conducted and give some results (the level of detail varies for different investigations) from most of the investigations carried out. The investigations carried out by other institutions than IMR (Norway) and PINRO (Russia), for instance the seabird observations, are mainly reported elsewhere.

Scientific papers, where the analysis is based on data from these surveys, may be found in various international journals.

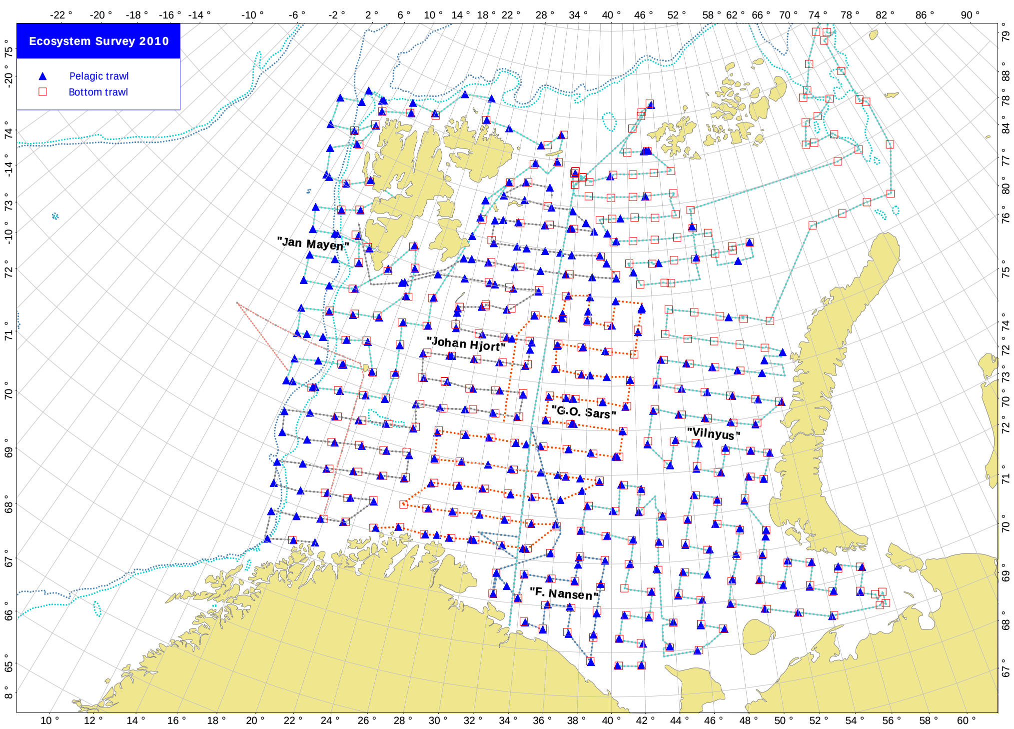

Figure 5.1.1. Map showing the surveyed area in 2010 (only stations with pelagic trawl and bottom trawl are shown here).

5.2 German Small-scale Bottom Trawl Survey (GSBTS)

5.2.1 Main purpose

Combined monitoring of groundfish communities, benthos and habitat parameters. The survey focuses on small-scale processes, i.e. within permanent areas of investigation of 10 x 10 nm size ('boxes'), which are sampled intensely. Locations of the boxes have been chosen to represent important hydrographical units within the North Sea (Figure 5.2.1, Ehrich *et al.*, 2009).

5.2.2 Aspects of ecosystem investigated, potential indicators supplied with data

Groundfish	Abundance, total weight and length spectra of all species caught	• Biodiversity indicators for fish => MSFD descriptor D1 (Biological diversity) • Size spectra / large fish indicator (on the respective spatial scale) => MSFD D4 (Foodwebs)
Benthos epifauna	Abundance and total weight of all species caught	MSFD D6 (Sea floor integrity)
Hydrography	Profiles	MSFD D7 (Hydrographical conditions)
Seabirds	Abundance (Seabirds at sea-program)	MSFD D4 (Foodwebs)
Sediments	Grain size composition	(MSFD D6 suitable? – indicators to be defined)
Nutrients	Concentrations dissolved N and P	(MSFD D5 -Eutrophication - suitable? – indicators yet to be defined)

5.2.3 Lessons learned

- The survey was initiated as a groundfish survey with synoptic records of hydrography and water chemistry. After the first few years, its potential to serve as an ecosystem survey was discerned and consequently, additional components have been investigated:
- => Sampling of benthic epifauna has been included as regular component of the survey in 1998/'99. Benthic infauna (much more labour-intensive) was analysed in individual years. Bird observations for the "Seabirds at sea" program have been included as regular component in 2005.
- Expansion to more than 6 boxes required involvement of a second vessel. Effects of between-vessel differences need to be taken into account. Obviously, constraints of the vessels sizes (here, 65 m vs. 41 m) and number of scientists aboard (12 vs. 7) determine the amount of possible additional sampling.
- The survey is suitable to record long-term shifts in local fish assemblages (e.g. Figure 5.2.2).

5.2.4 Survey method

Spatial scale	Area covered: North Sea, 12 areas of investigation ("boxes"), 10 x 10 nautical miles, each	Per box: 21 GOV hauls (groudfish); 15 CTD profiles; 9 2-m beam trawls (benthos); 9 grab samples (sediments)
Sampling scheme	Yearly, summer (Q3), since 1987 [Box A additionally sampled in Q1, annually]	Number of boxes increased from 4 in 1987 to 12 (last box added in 2003)
Selection of stations	Random selection of station positions and haul directions within box	
Main gear	GOV (6 Boxes, vessel 1) Cod Hopper (6 Boxes, smaller vessel 2)	(1) Using IBTS standard methodology (2) Net adapted to vessel capability, otherwise same methods
Parameters/ data taken	Groundfish, benthic epifauna, seabirds, hydrography, nutrients, sediments	
Additional sampling realized	Benthic infauna	Individual years and selected boxes (1999, 2003, 2004, 2007-current)
	Stomach sampling of selected fish species	Repeatedly, selected years
	Samples for parasitology of fish	2010
	Samples for genetic diversity of marine species (bar-coding)	2010, planned for 2011

Reference for methods:

Ehrich, *et al.* (2007): Ehrich, S., Adlerstein, S., Brockmann, U., Floeter, J., Garthe, S., Hinz, H., Kröncke, I., Neumann, H., Reiss, H., Sell, A.F., Stein, M., Stelzenmüller, V., Stransky, C., Temming, A., Wegner, G., Zauke, G.-P. 2007. 20 years of the German Small-Scale Bottom Trawl Survey (GSBTS): A review. Senckenbergiana maritime, 37(1): 13–82.

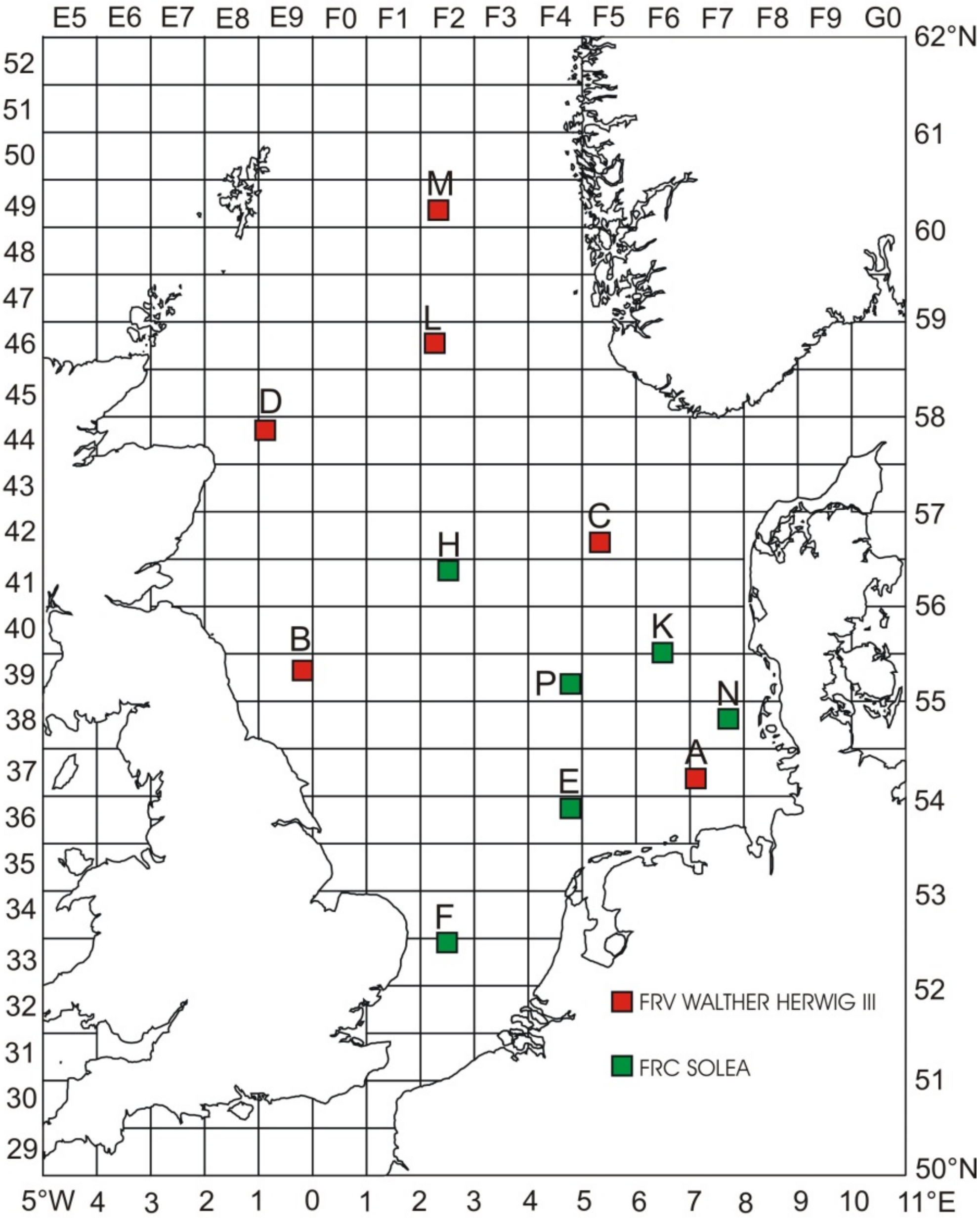

Figure 5.2.1. Map showing sampling areas by the two vessels involved in the GSBTS.

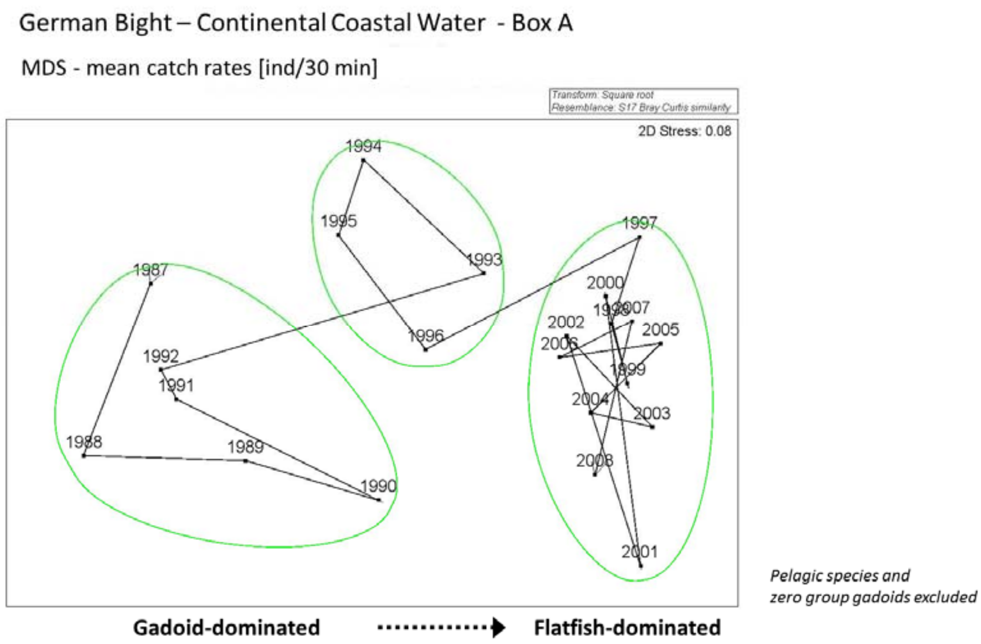

Figure 5.2.2. Example of a small-scale observation based on temporal analysis of survey results: Multi dimensional scaling plot for one of the "boxes" showing different fish community groupings, with a transition from a gadoid-dominate assemblage until 1992 to a flatfish-dominated assemblage after 1996.

5.3 UK Western Channel Beam Trawl Survey (Q1SWBeam)

5.3.1 Main purpose

The main purpose of this monitoring program is to assess flatfish abundance and distribution, but the basis of the stratified random survey design has always been to take account of the different habitats found in the western English Channel. Strata were developed in conjunction with fishers, using their knowledge of grounds and spatio-temporal distributions of fish as well as a number of physical characteristics, such as depth, summer stratification of the water column and sediment types.

It is the stratification scheme in conjunction with the flexibility of the stratified random design that made this survey ideally suited to trial a truly multidisciplinary survey in 2009. The stratification scheme had been found to be efficient for the assessment of flatfish abundance and the aim was to determine whether these strata were also useful to assess other ecosystem components or whether smaller more detailed strata would be required to do so effectively.

5.3.2 Aspects of ecosystem investigated, potential indicators supplied with data (1)

Groundfish Pelagic fish	Abundance, total weight and length spectra of all species caught. Multi-frequency fisheries Acoustics for assessing pelagic component of ecosystem.	Biodiversity indicators for fish => MSFD descriptor D1 (Biological diversity) Size spectra / large fish indicator (on the respective spatial scale) => MSFD D4 (Foodwebs)
Benthos – epifauna	Presence absence plus all benthos total. (In 2009 abundance and total weight of all species caught)	MSFD D6 (Sea floor integrity)
Hydrography	Profiles (Salinity, temperature)	MSFD D7 (Hydrographical conditions)
Seabirds and mammals	Observer in 2009 only (Seabirds at sea-program)	MSFD D4 (Foodwebs)
Sediments	2009 only: NIOZ core (samples for sediment porosity, sediment chl-a, infauna, redox profiles, particle size analysis) SPI camera (images to determine sediment processes and seabed integrity)	(MSFD D6 suitable? – indicators to be defined)
Nutrients	Concentrations dissolved N, P, oxygen, chl-a (continuous at surface and bottom samples at stations)	(MSFD D5 (Eutrophication) suitable? – indicators yet to be defined)
Bathymetry	Multi-beam sonar collecting bathymetry and hardness characteristics for habitat identification, also QTC ground discrimination from Fisheries Sounders	
HD video transects	2009 only: On a small number of stations 20 minute video transects in accordance with MESH protocol collected to describe habitat and identify species.	

5.3.3 Lessons learned

- Initial indications are that groundfish, infauna, sediment processes, productivity / nutrients are compatible with the stratification scheme of the survey, while sediments composition tends to vary at much smaller scales.
- A number of gear conflicts, especially with respect to mammal / bird observers and fishing activity and interference between different acoustic instruments proved to be difficult to resolve.
- Different gears have different sensitivities to sea and weather conditions requiring a set decision-making process when deciding whether to omit some gears from a station or wait till the conditions become appropriate to the most sensitive gear.
- Staff and expertise considerations are important when putting together multidisciplinary cruises and special operational requirements and good team work are essential. Staff must be prepared to lead / train in their discipline and help and learn in all the other disciplines.

- Cost of the survey were increased by about 65% and duration increased in length by 50%. This does not take into consideration that potentially it is possible to make substantial savings if this work negates or reduces the reliance on single discipline surveys.

5.3.4 Survey method

Spatial scale	Area covered: Western English Channel, ICES division VIIe plus two rectangles in VII H, stratified into 13 strata (Figure 2)	Aiming for a total of 80 samples per year and a minimum of 5 samples per stratum.
Sampling scheme	Yearly, March (Q1), since 2006, only 2009 fully multidisciplinary	
Selection of stations	Two stage random selection process without replacement in each of 13 strata. Minimum of 5 samples per stratum, with higher sampling effort in strata of fisheries importance.	
Main gear	2 * 4m beam trawls, one with a 40mm blinder to improve benthos and small fish selectivity.GOV	• Using WGBEAM standard processing and data collection methodology. • Standardised gear specific to this survey modified for robustness.
Parameters/ data taken	Groundfish, benthos presence absence, 2 hydrographic stations per day.	
Additional sampling realized	Multi-beam and multi frequency fisheries sounders for bathymetry, habitat discrimination and pelagic ecosystem assessment.	2007-Multi-beam 2007,2009–2010 QTC
	Multi-disciplinary implementation in 2009, see gears and collections above	Individual years (2009)

Reference for methods:

The full methodology and sampling design is currently not publically available. For further information please contact sven.kupschus@cefas.co.uk

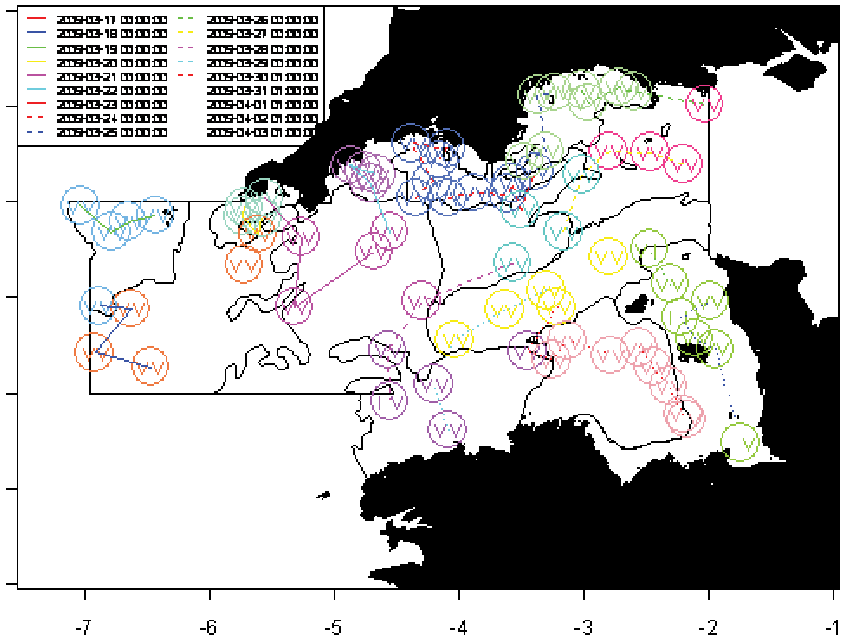

Figure 5.3.1. Beam trawl sampling station validity, positions and cruise track for 2009 stratified random sampling.

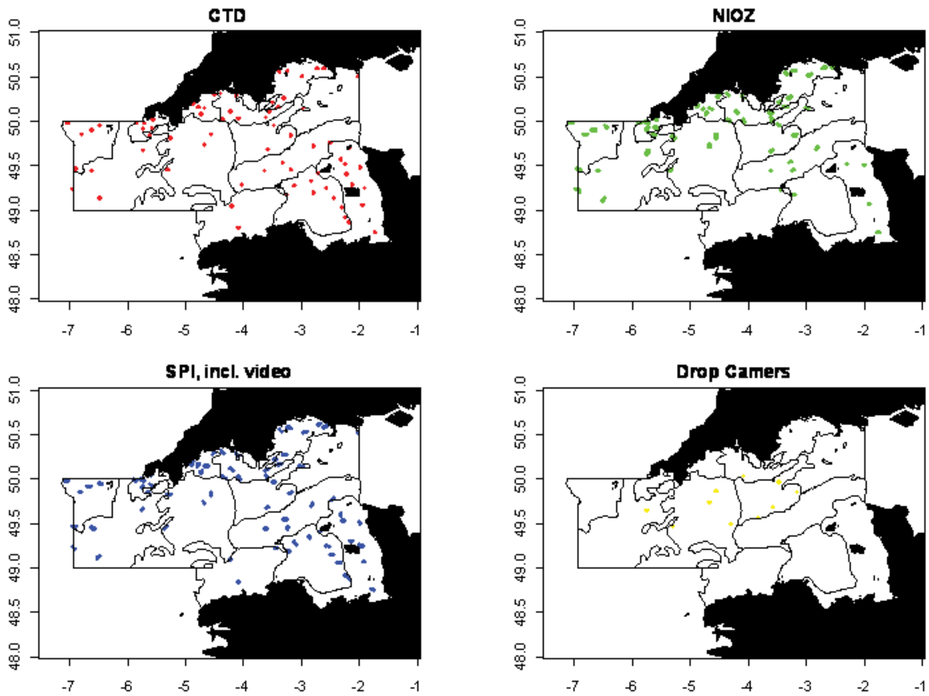

Figure 5.3.2. Location of valid environmental gear deployments by gear type.

6 References

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